

LINKED SUSPENSION SYSTEM FOR A VEHICLE

Background of the Invention

5 This invention relates to a suspension system suitable for use with a vehicle, and more particularly to a snowmobile track suspension system wherein the front and rear arms of the suspension are coupled such that the position of the front of the track suspension is determined at least in part by the position of the rear of the track suspension.

10 Suspension systems for vehicles are well-known. Generally, suspension systems provide a cushioning effect between the body of the vehicle and the surface on which the vehicle travels. This reduces the unwanted motions produced when the vehicle travels over an irregular surface, thereby enabling greater control and safety of operation, as well as providing a more comfortable ride.

15 Typical suspension systems utilize one or more shock absorbers with springs, hydraulic or pneumatic cylinders, etc., which extend and retract to keep the vehicle in contact with the surface over which it is moving, and which damp themselves to dissipate the energy absorbed in such motion.

 Conventional suspension systems may be either unified or independent.

20 Neither type has been entirely satisfactory.

 Unified suspension systems utilize a single shock absorber for the vehicle. Unified suspension systems are of only limited value in absorbing unwanted motions. Although they do provide some cushioning, the entire rear suspension is controlled by a single shock absorber. This can cause considerable mechanical stress to
25 both vehicle and passengers, and may result in part of the vehicle losing contact with the surface on which it is traveling.

 Independent suspension systems utilize two or more shock absorbers for different parts of the rear suspension. For example, it is known to provide front and rear shock absorbers to control the front and rear halves of a rear suspension separately.

30 Independent suspension systems can absorb motion from uneven terrain more easily,

and are more effective at keeping the vehicle in contact with the surface. However, if one of the shock absorbers is required to retract in order to absorb a large motion while the other is not, the vehicle will naturally pitch. An extreme pitch can result in a harsh ride.

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Summary of the Invention

Therefore it is the purpose of the present invention to overcome the deficiencies of the existing designs. It is the purpose of the present invention to provide a suspension system suitable for use with a vehicle that enables generally independent movement of at least two shock absorbers, but that also provides motive coupling
10 between the shock absorbers, so that under certain circumstances the motion of one shock absorber will produce motion in the other.

An embodiment of a suspension system in accordance with the principles of the present invention comprises first and second shock absorbers connected to a vehicle. The first shock absorber comprises a first main piston, and the second shock
15 absorber comprises a second main piston. The first and second shock absorbers are motively linked in such a way that when the first main piston retracts, the second main piston also retracts.

It is preferable that the first and second shock absorbers are hydraulic shock absorbers. It is also preferable that the first shock absorber defines a first
20 hydraulic chamber therein, and that the second shock absorber defines a second hydraulic chamber therein, and that the first and second hydraulic chambers are in hydraulic communication, as by a hydraulic line. As the first main piston retracts, the volume of the first hydraulic chamber decreases. This forces part of the volume of the fluid to be transferred to the second hydraulic chamber, which increases the volume of
25 the second hydraulic chamber, which in turn causes the second main piston to retract.

A variety of additional advantages of the invention will be set forth in part in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The advantages of the invention will be realized and attained by means of the elements and combinations particularly pointed
30 out in the claims. It is to be understood that both the foregoing general description and

the following detailed description are exemplary and explanatory only and are not restrictive of the invention as claimed.

Brief Description of the Drawings

Like reference numbers generally indicate corresponding elements in the
5 figures.

Figure 1 is a perspective view of an embodiment of a suspension system in accordance with the principles of the present invention.

Figure 2 is a schematic view of an embodiment of a suspension system in accordance with the principles of the present invention, wherein the first main piston
10 is in the extended position.

Figure 3 is a schematic view of the embodiment shown in Figure 2, wherein the first main piston is in the retracted position.

Detailed Description of the Preferred Embodiment

Referring to Figure 1, the present invention comprises a suspension
15 system **10** suitable for use with a vehicle. As illustrated, the suspension system **10** is comprised of suspension rails **14** and wheels **16**, as would be suitable for a snowmobile. Details of the drive system, steering system, passenger saddle, etc. are omitted for ease of understanding. It will be apparent to those knowledgeable in the art that the present invention may also be suitable for use with other vehicles, including but not limited to
20 motorcycles, four-wheelers, etc. Suitable vehicles are well-known, and are not described in detail herein.

As may be seen most easily in Figures 2 and 3, the suspension system **10** comprises a first shock absorber **20** and a second shock absorber **30**. It is envisioned that the first shock absorber **20** will be a rear shock absorber controlling and partially
25 supporting the rear of the suspension system **10**, and that the second shock absorber **30** will be a front shock absorber controlling and partially supporting the front of the suspension system **10**. However, it will be apparent to those knowledgeable in the art that such a configuration is exemplary only, and that other configurations may be equally suitable.

The first shock absorber **20** comprises a first body **21** and first main piston **22**, the first main piston **22** being moveably disposed within the first body **21**. The first main piston **22** is moveable between a retracted position, wherein it is substantially retracted into the first body **21**, and an extended position, wherein it is substantially extended from the first body **21**.

The second shock absorber **30** comprises a second body **31** and a second main piston **32**, the second main piston **32** being moveably disposed within the second body **31**. The second main piston **32** is moveable between a retracted position, wherein it is substantially retracted into the second body **31**, and an extended position, wherein it is substantially extended from the second body **31**.

The first and second shock absorbers **20** and **30** are movably linked with one another such that when the first main piston **22** is moved towards the retracted position, the second main piston **32** is caused to move towards the retracted position.

It will be apparent to those knowledgeable in the art that this configuration of two shock absorbers is exemplary only, and that other numbers of shock absorbers may be equally suitable.

It is preferable that the first and second shock absorbers **20** and **30** are hydraulic shock absorbers, as hydraulic shock absorbers are easily adapted to the needs of the present invention. However, it will be apparent to those knowledgeable in the art that this design is exemplary only, and that other shock absorbers, including but not limited to pneumatic shock absorbers, may be equally suitable.

The first main piston **22** comprises a first main piston head **24** disposed at a first end **26** of the first main piston **22**. The first body **21** defines a first hydraulic chamber **28** therein, the first main piston head **24** being movably disposed within the first hydraulic chamber **28**. In such a configuration, the volume inside the first hydraulic chamber **28** is smaller when the first main piston **22** is in the retracted position than when the first main piston **22** is in the extended position.

Advantageously, the first main piston head **24** comprises a first damping valve mechanism **25** for enabling fluid flow through the first main piston head **24** in a

controlled manner, so as to minimize cavitation as the first main piston head **24** moves within the first hydraulic chamber **28**.

When a first damping valve mechanism **25** is present, it will be appreciated that the first main piston head **24** and the first main piston **22** must be configured relative to the first hydraulic chamber **28** such that fluid within the first hydraulic chamber **28** flows through the first damping valve mechanism **25** of the first main piston head **24** as the first main piston **22** moves between its extended and retracted positions. Advantageously, the first main piston **22**, the first main piston head **24**, and the first hydraulic chamber **28** are configured such that cavitation within the first hydraulic chamber **28** is avoided or at least minimized as the first main piston **22** and the first main piston head **24** move within the first hydraulic chamber **28**.

The second main piston **32** comprises a second main piston head **34** disposed at a first end **36** of the second main piston **32**. In the embodiment illustrated, the second shock absorber **30** comprises a separator piston head **38**, the separator piston head **38** being moveable independently of the second main piston **32**. Advantageously, the separator piston head **38** is moveably disposed on the second main piston **32** proximate the second main piston head **34**. The second body **31** and the separator piston head **38** cooperate to define a second hydraulic chamber **40** within the second shock absorber **30**. The second shock absorber **30** is configured such that increasing the volume of the second hydraulic chamber **40** causes the separator piston head **38** to press against the second main piston head **34** and/or any hydraulic fluid between the separator piston head **38** and the second main piston head **34**, which in turn pushes on the second main piston head **34** thereby causing the second main piston **32** to move toward the retracted position.

Advantageously, the second main piston head **34** comprises a second damping valve mechanism **35** for enabling fluid flow through the second main piston head **34** in a controlled manner, so as to minimize cavitation as the second main piston head **34** moves within the third hydraulic chamber **40**.

When a second damping valve mechanism **35** is present, it will be appreciated that the second main piston head **34** and the second main piston **32** must be

configured relative to the third hydraulic chamber **40** such that fluid within the third hydraulic chamber **40** flows through the second damping valve mechanism **35** of the second main piston head **34** as the second main piston **32** moves between its extended and retracted positions. Advantageously, the second main piston **32**, the second main piston head **34**, and the third hydraulic chamber **40** are configured such that cavitation within the third hydraulic chamber **40** is avoided or at least minimized as the second main piston **32** and the second main piston head **34** move within the third hydraulic chamber **40**.

The first and second hydraulic chambers **28** and **40** may be in hydraulic communication. Hydraulic communication may be made by a first hydraulic line **50**.

The first and second hydraulic chambers **28** and **40** are at least substantially filled with a first hydraulic fluid.

A variety of fluids may be suitable for use as the first hydraulic fluid. Advantageously, the first hydraulic fluid is a hydraulic oil. More advantageously, the first hydraulic fluid is a synthetic hydraulic oil.

The first hydraulic fluid may be a cavitation-resistant synthetic hydraulic oil. Cavitation is the formation and subsequent collapse of voids or bubbles within a fluid, generally caused by rapid and/or turbulent flow of or motion within the fluid.

A variety of suitable oils are available that resist physical and chemical breakdown caused by cavitation, and/or resist cavitation itself. Known cavitation-resistant synthetic oils include but are not limited to Maxima and Amzoil.

Advantageously, the first hydraulic fluid is a medium weight oil.

The suspension system **10** may comprise a restrictor **51** disposed between the first and second hydraulic chambers **28** and **40**, so as to control fluid flow between the first and second hydraulic chambers **28** and **40**. Advantageously, the restrictor **51** is adapted to prevent or at least reduce cavitation of the first hydraulic fluid by controlling the flow of fluid between the first and second hydraulic chambers **28** and **40**.

Advantageously, the restrictor **51** is disposed in line with the first hydraulic line **50**.

A variety of restrictors **51** suitable for use with the suspension system **10** are known, and are not further described herein.

As may be seen in Figures 2 and 3, in such a configuration, when the first main piston **22** is moved toward the retracted position, the volume of the first hydraulic chamber **28** is decreased, whereby the volume of the second hydraulic chamber **40** is increased, whereby the second main piston **32** is caused to move towards the retracted position.

In the configuration illustrated in Figures 2 and 3, the first and second main pistons **22** and **32** may be said to be “in phase”. That is, when the first main piston **22** moves towards its retracted position, so does the second main piston **32**. The second main piston **32** may undergo substantial independent movement.

In other words, when the first main piston **22** retracts, the second main piston **32** retracts similarly. However, motion of the second main piston **32** does not necessarily cause similar motion of the first main piston **22**.

The second body **31** and the second main piston head **34** cooperate to define a third hydraulic chamber **42** within the second shock absorber **30**.

The third hydraulic chamber **42** is at least substantially filled with a second hydraulic fluid.

A variety of fluids may be suitable for use as the second hydraulic fluid. Advantageously, the second hydraulic fluid is a hydraulic oil. More advantageously, the second hydraulic fluid is a synthetic hydraulic oil.

The second hydraulic fluid may be a cavitation-resistant synthetic hydraulic oil.

Advantageously, the second hydraulic fluid is a medium weight oil.

It will be apparent to those knowledgeable in the art that this particular configuration of shock absorbers is exemplary only, and that other configurations may be equally suitable.

It will be appreciated that, when the second main piston **32** is in the extended position, the separator piston head **38** is in contact with the extended end **41** of the second hydraulic chamber **40**. If the separator piston head **38** and the extended end

41 are configured in such a way as to trap only a thin, uniform film of fluid therebetween when the second main piston 32 is in the extended position, the separator piston head 38 and the extended end 41 may become stuck due to adhesion therebetween via the first hydraulic fluid.

5 Therefore, in an advantageous embodiment the portion of the separator piston 38 that comes in close contact with the extended end 41 has a size and/or shape so as to prevent formation of a thin uniform film of fluid therebetween, and thereby to avoid sticking.

10 In an alternative advantageous embodiment, the second shock absorber 30 comprises an anti-stick mechanism 43 disposed between the separator piston head 38 and the extended end 41. One suitable anti-stick mechanism 43 is a spacer disposed on the second main piston 32. A spacer having a thickness of as little as approximately .040" may be sufficient to prevent sticking. However, it will be appreciated that alternative anti-stick mechanisms may be equally suitable.

15 The second hydraulic chamber 40 may comprise a central portion 44 and a passage portion 46. The central portion 44 is generally adjacent to the third hydraulic chamber 42, the two being separated by the separator piston 38. The passage portion 46 is configured so as to enable a connection 48 for the first hydraulic line 50 to be mounted to the second shock absorber 30 in a convenient position. The passage portion 20 46 and the central portion 44 are in hydraulic communication with one another. This provides a convenient system for delivering the first hydraulic fluid from first hydraulic line 50 to the central portion 44.

Advantageously, the passage portion is configured so as to avoid or at least minimize cavitation of fluid flowing therein.

25 The passage portion 46 may comprise a plurality of holes or tubes disposed peripherally about the central portion 44. In particular, two holes each having a diameter of approximately .160" may be suitable.

Alternatively, a passage portion generally in the shape of a hollow, cylindrical shell may be suitable.

It will be apparent to those knowledgeable in the art that these configurations are exemplary only, and that other configurations may be equally suitable.

It is preferable that the suspension system **10** comprises an adjustor **70** for adjusting the suspension system **10**. The adjustor **70** allows the “trim”, that is, the neutral position of the first and second main pistons, of the suspension system **10** to be set to a desired level.

The adjustor **70** may comprise an adjustor body **71** and an adjustor piston **72**, the adjustor piston **72** being moveably disposed within the adjustor body **71**. The adjustor piston **72** is advantageously moveable between a retracted position, wherein it is substantially retracted into the adjustor body **71**, and an extended position, wherein it is substantially extended from the adjustor body **71**.

The adjustor piston **72** comprises an adjustor piston head **74** at a first end thereof. The adjustor body **71** and the adjustor piston head **74** cooperate to define a fourth hydraulic chamber **78** and a first pneumatic chamber **80** within the adjustor body **71**. As illustrated in Figures 2 and 3, the adjustor **70** is configured such that moving the adjustor piston **72** toward the retracted position causes the volume of the fourth hydraulic chamber **78** to decrease and the volume of the first pneumatic chamber **80** to increase correspondingly, and that moving the adjustor piston **72** toward the extended position causes the volume of the fourth hydraulic chamber **78** to increase and the volume of the first pneumatic chamber **80** to decrease correspondingly. However, this arrangement is exemplary only, and other arrangements may be equally suitable.

In the embodiment illustrated in Figures 2 and 3, decreasing the volume of the fourth hydraulic chamber **78** makes a corresponding additional volume of the first hydraulic fluid available to the first and second hydraulic chambers **28** and **40**. However, a given change in the volume of the first hydraulic chamber **28** causes a change in the position of the first main piston **22** that is greater than the change in position of the second main piston **32** for an equal change in volume of the second hydraulic chamber **40**. Thus, in the embodiment illustrated in Figures 2 and 3, decreasing the volume of the fourth hydraulic chamber **78** causes the second main

piston **32** to move towards its retracted position. This in turn causes the first main piston **22** to move towards its extended position. Conversely, increasing the volume of the fourth hydraulic chamber **78** causes the second main piston **32** to move towards its extended position, which in turn causes the first main piston **22** to move towards its retracted position.

It will be appreciated that this arrangement is exemplary only, and that the motions of the first and second main pistons **32** and **40** in response to a motion of the adjustor piston **72** may be different for other embodiments of the suspension system **10**.

The fourth hydraulic chamber **78** is in hydraulic communication with at least one of the first hydraulic chamber **28**, the second hydraulic chamber **40**, and the first hydraulic line **50**. Hydraulic communication may be enabled by a second hydraulic line **52**. The fourth hydraulic chamber **78** is at least substantially filled with the first hydraulic fluid.

The first pneumatic chamber **80** is filled with a first pneumatic fluid. The first pneumatic fluid may be air.

The adjustor piston **72** may comprise adjusting means **82** for enabling convenient adjustment of its position. Suitable adjusting means include but are not limited to screw threads.

The adjustor piston **72** may comprise manipulation means **84** for convenient manipulation of the adjustor piston **72**. Suitable means include but are not limited to twist knobs, screw heads, and bolt heads.

The adjustor piston **72** may comprise locking means **86** for securing the adjusting means **82** so that the adjustor piston **72** may be secured in position when it is not being adjusted. Suitable locking means include but are not limited to locking nuts.

It will be apparent to those knowledgeable in the art that this adjustor mechanism is exemplary only, and that suspension systems with other adjustor mechanisms, or no adjustor mechanism, may be equally suitable. In particular, it will be apparent that adjustors without a pneumatic chamber, or having a chamber that is open to the air, may be equally suitable.

It is preferable that the suspension system **10** comprises a remote reservoir mechanism **90** for accommodating motions of the first and second main pistons **22** and **32**. As illustrated in Figures 2 and 3, this may be accomplished by accommodating changes in the volumes of the first and second hydraulic chambers **28** and **40**.

The remote reservoir mechanism **90** comprises a reservoir body **91** and a remote reservoir piston head **92**, the remote reservoir piston head **92** being moveably disposed within the reservoir body **91**. The reservoir body **91** and the remote reservoir piston head **92** cooperate to define a fifth hydraulic chamber **94** and a pressure means chamber **96** within the reservoir body **91**. The remote reservoir mechanism **90** is configured such that an increase in the volume of the fifth hydraulic chamber **94** causes a corresponding decrease in the volume of the pressure means chamber **96**, and that a decrease in the volume of the fifth hydraulic chamber **94** causes a corresponding increase in the volume of the pressure means chamber **96**. The relative motions of the fifth hydraulic chamber **94** and the pressure means chamber **96** act to compensate for the changes in volume of the third hydraulic chamber **42**, as when the second main piston **32** is retracted, when the volume of the fourth hydraulic chamber **78** in the adjustor **70** changes, or when the volume of the first hydraulic chamber **28** in the first shock absorber **20** changes.

The fifth hydraulic chamber **94** is in hydraulic communication with the third hydraulic chamber **42**. Hydraulic communication may be made by a third hydraulic line **54**.

The fifth hydraulic chamber **94** is at least substantially filled with the second hydraulic fluid.

The pressure means chamber **96** comprises pressure means **97** therein for exerting pressure against the reservoir piston head **92**. A variety of pressure means may be suitable.

In an advantageous embodiment, the pressure means **97** comprises a second pneumatic fluid disposed within the pressure means chamber **96**. The second pneumatic fluid is advantageously under sufficient pressure to eliminate or at least

minimize cavitation of the second hydraulic fluid within and proximate to the fifth hydraulic chamber 94. The second pneumatic fluid may be compressed nitrogen. The second pneumatic fluid may alternatively be compressed air.

5 In another advantageous embodiment, the pressure means 97 comprises a compression spring disposed within the pressure means chamber 96.

It will be apparent to those knowledgeable in the art that this remote reservoir mechanism is exemplary only, and that other remote reservoir mechanisms or no remote reservoir mechanism at all may be equally suitable.

10 The suspension system 10 may comprise a bleed-back valve 55 disposed between the third and fifth hydraulic chambers 42 and 94, so as to control fluid flow between the third and fifth hydraulic chambers 42 and 94. Advantageously, the bleed-back valve 55 is adapted to adjustably control the flow of fluid between the third and fifth hydraulic chambers 42 and 94. Control of the flow of fluid between the third and fifth hydraulic chambers 42 and 94 affects the rate at which the first and second shock
15 absorbers 20 and 30 "rebound", or return to their original positions.

Advantageously, the bleed-back valve 55 is disposed in line with the third hydraulic line 54.

Advantageously, the bleed-back valve 55 is adapted to control the flow of fluid between the third and fifth hydraulic chambers 42 and 94 to such a degree that
20 the first and second shock absorbers 20 and 30 provide compressive damping in addition to rebound damping.

A variety of bleed-back valves 55 may be suitable for use with the suspension system 10. For example, a metering rod having a needle and seat arrangement may be suitable. However, bleed-back valves are known, and are not
25 further described herein.

The suspension system 10 may comprise o-rings for sealing various components.

In particular, the separator piston head 38 may comprise an o-ring 39 adapted to prevent fluid flow between the second and third hydraulic chambers 40 and
30 42.

Similarly, the adjustor piston head **74** may comprise an o-ring **75** adapted to prevent fluid flow between the fourth hydraulic chamber **78** and the first pneumatic chamber **80**.

5 Likewise, the damping piston head **92** may comprise an o-ring **93** adapted to prevent fluid flow between the fifth hydraulic chamber **94** and the second pneumatic chamber **96**.

Additionally, the first shock absorber **20** may comprise an o-ring **23** between the first body **21** and the first main piston **22** to prevent leakage of fluid from the first hydraulic chamber **28**.

10 Similarly, the second shock absorber **30** may comprise an o-ring **33** between the second body **31** and the second main piston **32** to prevent leakage of fluid from the second hydraulic chamber **40**.

15 Likewise, the adjustor **70** may comprise an o-ring **73** between the adjustor body **71** and the adjustor piston **72** to prevent leakage of fluid from within the adjustor **70**.

However, it will be appreciated that these o-rings are exemplary only, and that embodiments lacking any or all, or having additional o-rings, or having o-rings located elsewhere, may be equally suitable.

20 Advantageously, the o-rings **23**, **33**, **39**, **73**, **75**, and **93** are made of material that resists degradation by the fluids with which they come in contact. For example, when the first and second hydraulic fluids are synthetic oils, the o-rings **23**, **33**, **39**, **73**, **75**, and **93** advantageously may be made of nitrile or fluoroelastomer. However, a variety of other materials may be equally suitable for use with synthetic oils, and with other fluids.

25 Suitable materials and fittings for shock absorbers beyond those described herein are well known, and are not detailed further herein.

It is noted that, although cavitation is preferably avoided for certain embodiments of the claimed invention, this is exemplary only.

Cavitation is known to contribute to the breakdown of certain hydraulic fluids. It also generally detrimental to the operation of conventional suspension systems.

5 However, cavitation does not inherently impair the operation of a suspension system **10** in accordance with the principles of the claimed invention. Certain embodiments may be fully operable even under conditions of extreme cavitation.

10 Furthermore, certain embodiments of a suspension system **10** in accordance with the principles of the claimed invention may derive a positive dynamic effect from cavitation.

15 The above specification, examples and data provide a complete description of the manufacture and use of the composition of the invention. Since many embodiments of the invention can be made without departing from the spirit and scope of the invention, the invention resides in the claims hereinafter appended.